

WHAT IS CLAIMED IS:

- 1 1. An apparatus comprising:
2 a first channel spatial filter, wherein a first input signal and a second input
3 signal are input to said first channel spatial filter, and wherein a first output signal is
4 output by said first channel spatial filter;
5 a second channel spatial filter, wherein a third input signal and a fourth
6 input signal are input to said second channel spatial filter, and wherein a second output
7 signal is output by said second channel spatial filter; and
8 a binaural spatial filter, wherein said first and second output signals are
9 input to said binaural spatial filter and wherein a first channel output signal is output by
10 said binaural spatial filter and a second channel output signal is output by said binaural
11 spatial filter.
- 1 2. The apparatus of claim 1, wherein said first input signal is output
2 by a first microphone corresponding to a first channel and said second input signal is
3 output by a second microphone corresponding to said first channel, and wherein said third
4 input signal is output by a third microphone corresponding to a second channel and said
5 fourth input signal is output by a fourth microphone corresponding to said second
6 channel.
- 1 3. The apparatus of claim 2, wherein said first microphone and said
2 second microphone are positioned in a first end-fire array and wherein said third
3 microphone and said fourth microphone are positioned in a second end-fire array.
- 1 4. The apparatus of claim 2, wherein said apparatus is a hearing aid,
2 wherein said first microphone and said second microphone are proximate to a user's left
3 ear, and wherein said third microphone and said fourth microphone are proximate to a
4 user's right ear.
- 1 5. The apparatus of claim 1, wherein said first channel spatial filter
2 further comprises:
3 a first fixed polar pattern unit, said first fixed polar pattern unit outputting
4 a first unit output;

5 a second fixed polar pattern unit, said second fixed polar pattern unit
6 outputting a second unit output; and
7 a first combining unit comprising a first adaptive filter, wherein said first
8 combining unit receives said first unit output and said second unit output, and wherein
9 said first combining unit outputs said first output signal.

1 6. The apparatus of claim 5, wherein said second channel spatial filter
2 further comprises:
3 a third fixed polar pattern unit, said third fixed polar pattern unit outputting
4 a third unit output;
5 a fourth fixed polar pattern unit, said fourth fixed polar pattern unit
6 outputting a fourth unit output; and
7 a second combining unit comprising a second adaptive filter, wherein said
8 second combining unit receives said third unit output and said fourth unit output, and
9 wherein said second combining unit outputs said second output signal.

1 7. The apparatus of claim 6, further comprising a processor, wherein
2 said first, second, third, and fourth fixed polar pattern units and said first and second
3 combining units are implemented by a software program running on said processor.

1 8. The apparatus of claim 7, wherein said processor is a digital
2 processor.

1 9. The apparatus of claim 1, said binaural spatial filter further
2 comprising:
3 a first combining unit, wherein said first combining unit combines said
4 first and second output signals and outputs a reference signal;
5 a first adaptive filter, said first adaptive filter receiving said reference
6 signal;
7 a second combining unit, wherein said second combining unit combines
8 said first output signal with a first adaptive filter output, and wherein said second
9 combining unit outputs said first channel output signal;
10 a second adaptive filter, said second adaptive filter receiving said reference
11 signal; and

a third combining unit, wherein said third combining unit combines said second output signal with a second adaptive filter output, and wherein said third combining unit outputs said second channel output signal.

10. The apparatus of claim 9, further comprising a processor, wherein said first, second, and third combining units and said first and second adaptive filters are implemented by a software program running on said processor.

11. The apparatus of claim 1, said binaural spatial filter further comprising:

a first channel low pass filter, said first channel low pass filter accepting said first output signal and outputting a first filtered output signal;

a first delay unit, said first delay unit accepting said first filtered output signal and outputting a delayed first filtered output signal;

a first channel high pass filter, said first channel high pass filter accepting said first output signal and outputting a second filtered output signal;

a second channel low pass filter, said second channel low pass filter accepting said second output signal and outputting a third filtered output signal;

a second delay unit, said second delay unit accepting said third filtered output signal and outputting a delayed third filtered output signal;

a second channel high pass filter, said second channel high pass filter accepting said second output signal and outputting a fourth filtered output signal;

an adaptive processor, said adaptive processor accepting said second and fourth filtered output signals and outputting an adaptively processed signal;

a first combining unit, said first combining unit accepting said delayed first filtered output signal and said adaptively processed signal, said first combining unit outputting said first channel output signal; and

a second combining unit, said second combining unit accepting said delayed third filtered output signal and said adaptively processed signal, said second combining unit outputting said second channel output signal.

12. A hearing aid, comprising:

a first microphone outputting a first microphone signal;

3 a second microphone outputting a second microphone signal, wherein said
 4 first and second microphones are positioned as a first end-fire array proximate to a user's
 5 left ear;

6 a third microphone outputting a third microphone signal;

7 a fourth microphone outputting a fourth microphone signal, wherein said
 8 third and fourth microphones are positioned as a second end-fire array proximate to a
 9 user's right ear;

10 a left spatial filter, said left spatial filter comprising:

11 a first fixed polar pattern unit, said first fixed polar pattern unit
 12 outputting a first unit output;

13 a second fixed polar pattern unit, said second fixed polar pattern
 14 unit outputting a second unit output; and

15 a first combining unit comprising a first adaptive filter, wherein
 16 said first combining unit receives said first unit output and said second unit output,
 17 and wherein said first combining unit outputs a left spatial filter output signal.

18 a right spatial filter, said right spatial filter comprising:

19 a third fixed polar pattern unit, said third fixed polar pattern unit
 20 outputting a third unit output;

21 a fourth fixed polar pattern unit, said fourth fixed polar pattern unit
 22 outputting a fourth unit output; and

23 a second combining unit comprising a second adaptive filter,
 24 wherein said second combining unit receives said third unit output and said fourth
 25 unit output, and wherein said second combining unit outputs a right spatial filter
 26 output signal;

27 a binaural spatial filter, said binaural spatial filter comprising:

28 a third combining unit, wherein said third combining unit combines
 29 said left spatial filter output signal and said right spatial filter output signal and
 30 outputs a reference signal;

31 a third adaptive filter, said third adaptive filter receiving said
 32 reference signal;

33 a fourth combining unit, wherein said fourth combining unit
 34 combines said left spatial filter output signal with a third adaptive filter output,
 35 and wherein said fourth combining unit outputs a left channel output signal;

36 a fourth adaptive filter, said fourth adaptive filter receiving said
37 reference signal; and
38 a fifth combining unit, wherein said fifth combining unit combines
39 said right spatial filter output signal with a fourth adaptive filter output, and
40 wherein said fifth combining unit outputs a right channel output signal;
41 a first output transducer, said first output transducer converting said left
42 channel output signal to a left channel audio output; and
43 a second output transducer, said second output transducer converting said
44 right channel output signal to a right channel audio output.

1 13. A method of processing sound, comprising the steps of:
2 receiving a first input signal from a first microphone;
3 receiving a second input signal from a second microphone;
4 providing said first and second input signals to a first fixed polar pattern
5 unit;
6 providing said first and second input signals to a second fixed polar pattern
7 unit;
8 adaptively combining a first fixed polar pattern unit output and a second
9 fixed polar pattern unit output to form a first channel binaural filter input;
10 receiving a third input signal from a third microphone;
11 receiving a fourth input signal from a fourth microphone;
12 providing said third and fourth input signals to a third fixed polar pattern
13 unit;
14 providing said third and fourth input signals to a fourth fixed polar pattern
15 unit;
16 adaptively combining a third fixed polar pattern unit output and a fourth
17 fixed polar pattern unit output to form a second channel binaural filter input;
18 combining said first channel binaural filter input and said second channel
19 binaural filter input to form a reference signal;
20 adaptively combining said reference signal with said first channel binaural
21 filter input to form a first channel output signal; and
22 adaptively combining said reference signal with said second channel
23 binaural filter input to form a second channel output signal.

1 14. The method of claim 13, further comprising the steps of:
2 converting said first channel output signal to a first channel audio signal;
3 and
4 converting said second channel output signal to a second channel audio
5 signal.

1 15. The method of claim 13, wherein said step of adaptively combining
2 said first fixed polar pattern unit output and said second fixed polar pattern unit output to
3 form said first channel binaural filter input further comprises the step of varying a first
4 gain value to position a first null corresponding to said first channel binaural filter input,
5 and wherein said step of adaptively combining said third fixed polar pattern unit output
6 and said fourth fixed polar pattern unit output to form said second channel binaural filter
7 input further comprises the step of varying a second gain value to position a second null
8 corresponding to said second channel binaural filter input.

1 16. The method of claim 13, wherein said steps of adaptively
2 combining utilize an LS algorithm.

1 17. The method of claim 13, wherein said steps of adaptively
2 combining utilize an RLS algorithm.

1 18. The method of claim 13, wherein said steps of adaptively
2 combining utilize an TLS algorithm.

1 19. The method of claim 13, wherein said steps of adaptively
2 combining utilize an NLMS algorithm.

1 20. The method of claim 13, wherein said steps of adaptively
2 combining utilize an LMS algorithm.